Observations of the Shortwave Direct Radiative Effect of Saharan Mineral Dust from SEVIRI and GERB

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Overview

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3. SWDRE Methodology
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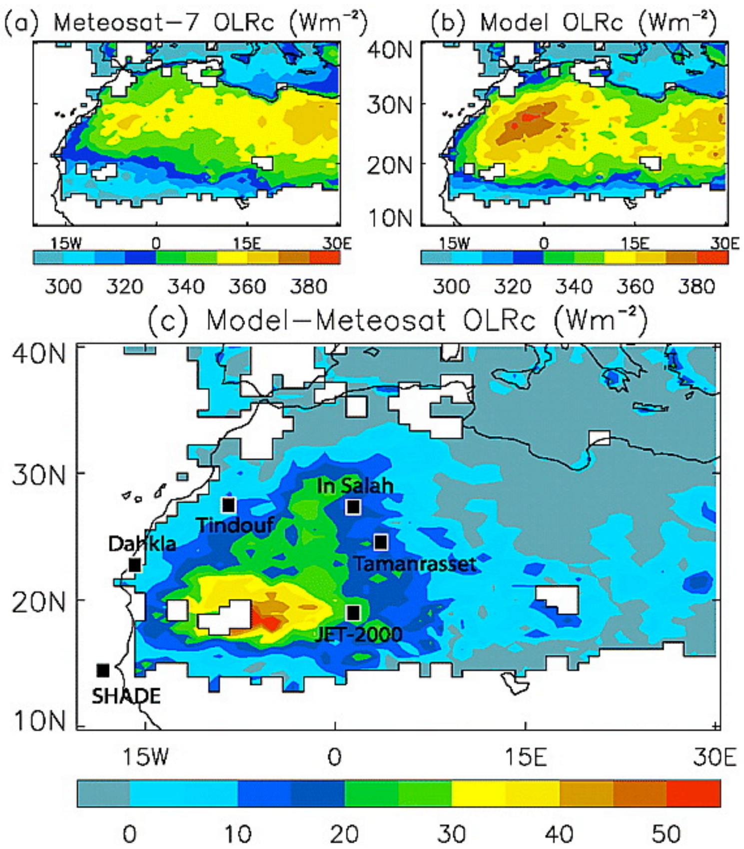
Motivations

The UK Met Office Unified Model (UKMO) currently does not assimilate aerosol into its forecasts.

Recent studies have shown significant OLR anomalies over North Africa which are believed to be a result of the lack of aerosol treatment eg. Haywood et al (2005).



UKMO recent test assimilation showed an increase in short term forecast capability.

Other studies by *Morcrette et al, Greed et al, Zhang et al* have incorporated dust into regional models and shown reductions in surface temperature bias due to better surface flux representation and improved AOD forecast.

Steps towards Assimilation

UKMO aims to assimilate AOD from SEVIRI (Brindley & Russell) into its Unified Model and ultimately compare the forecast fluxes with GERB observations.

Steps towards assimilation:

1. Validate SEVIRI AOD product

2. Assess DRE from GERB flux observations and co-located SEVIRI AOD retrievals to determine expected effect

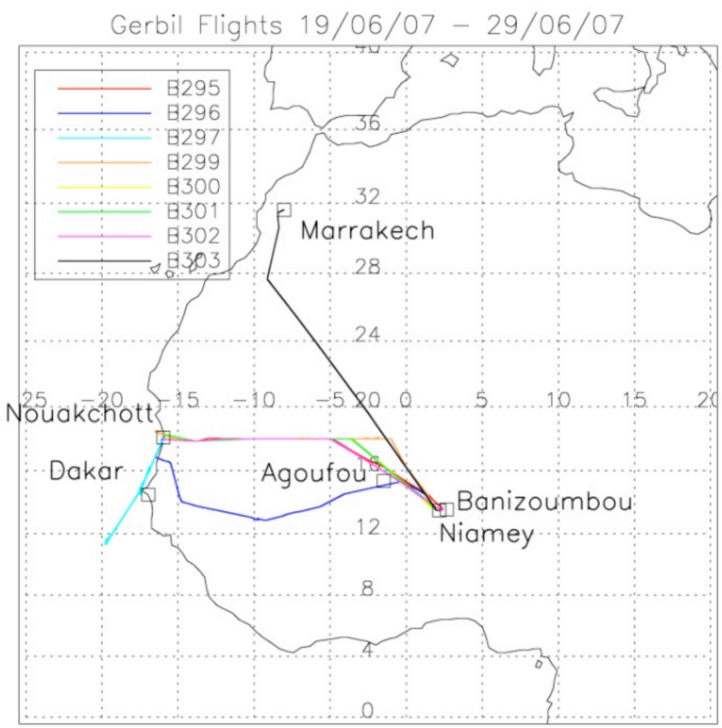
3. Test assimilation over the GERBILS period and compare fluxes to GERB observations

GERBILS

Geostationary Earth Radiation Budget Intercomparison of Longwave and Shortwave radiation .

FAAM airborne campaign consisting of 10 flights during 19 – 29/06/07 across West Africa.

This location specifically chosen to cover the area where the UM was found to have significant errors in flux simulations.



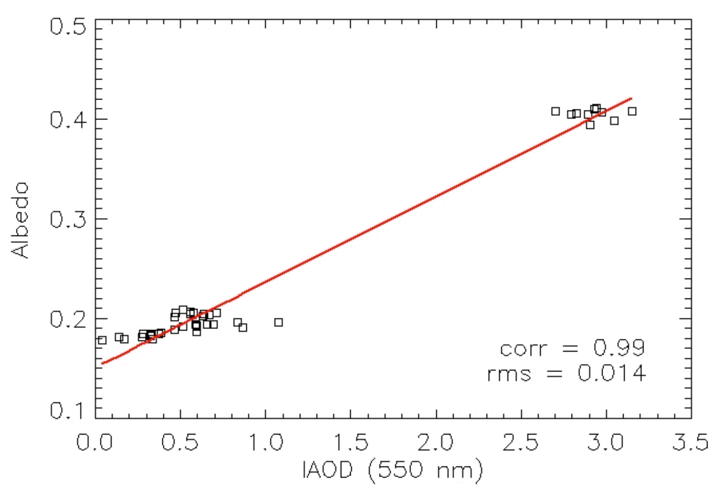
This period was used for validation of SEVIRI AOD using AERONET measurements and flight-based observations of AOD.

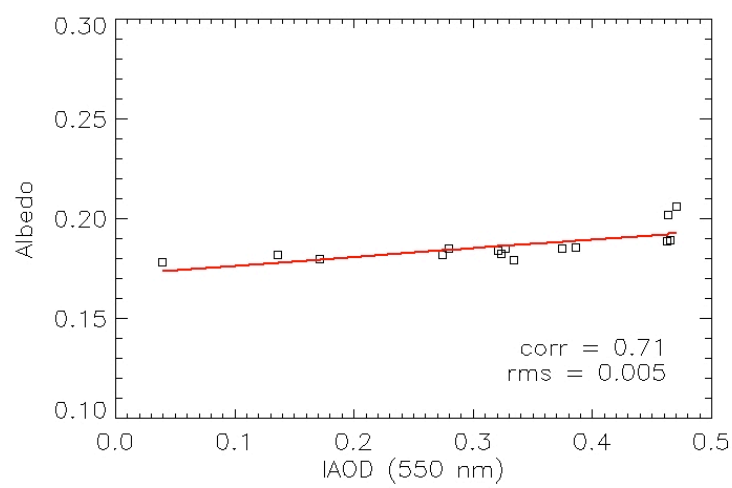
Can we determine the net DRE due to Saharan mineral dust aerosol for this period?

SWDRE Methodology

Determine pristine sky albedo for each 0.25° x 0.25° latitude-longitude box at 0900, 1200 & 1500 UTC. Similar methodology to *Chen et al* (2009).

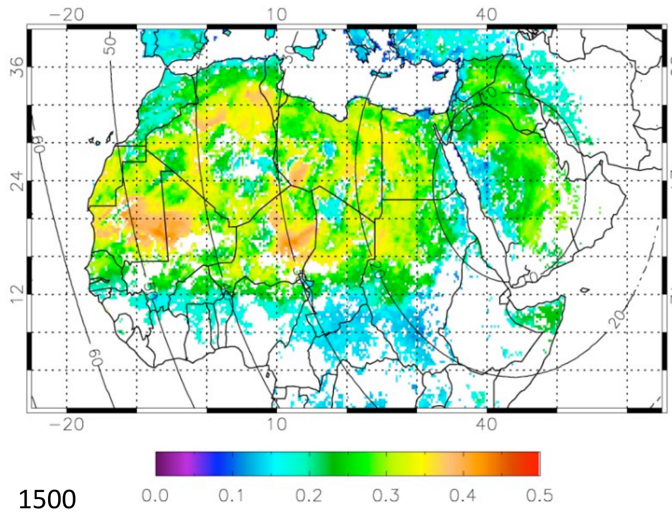
1. Linear regression performed between pairs of SEVIRI AOD (< 0.5) and GERB observations of SW albedo. Y-intercept of regression line represents the aerosol-free albedo for lat-lon box (α_p).
2. Conditions on successful α_p regression
   - n > 10
     - |correlation| > 0.5 or rms of regression < 0.025
     - AOD range > 0.15 (within AODs < 0.5)
3. SW DRE = $\alpha_p F_{\downarrow(obs)} - F_{\uparrow(obs)}$ (GERB HR Fluxes)



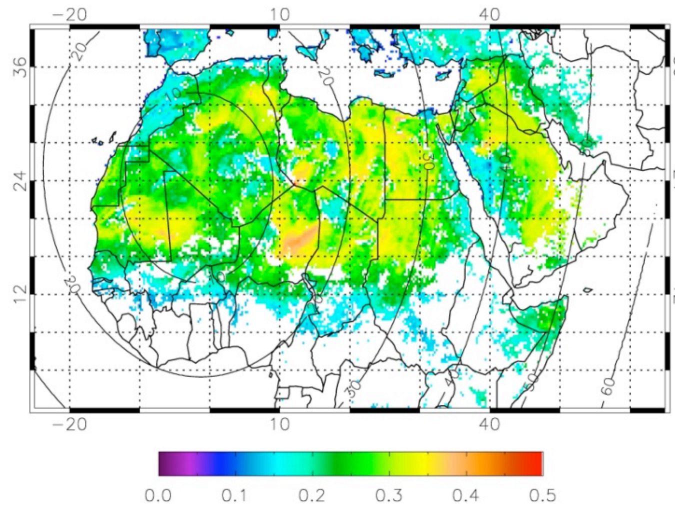


Derived Pristine Sky

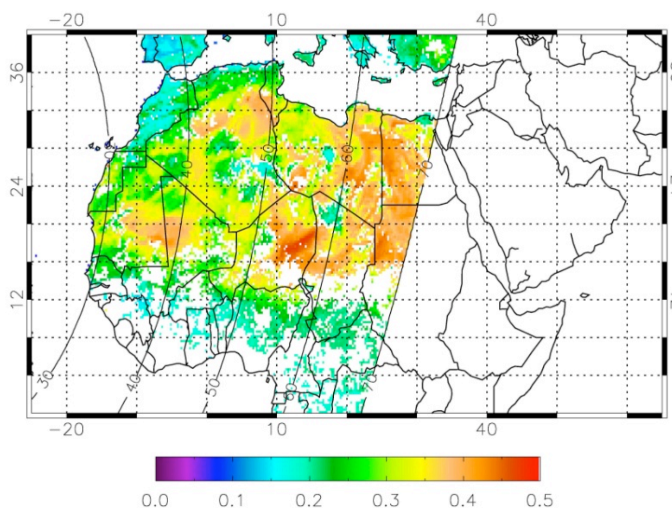
0900

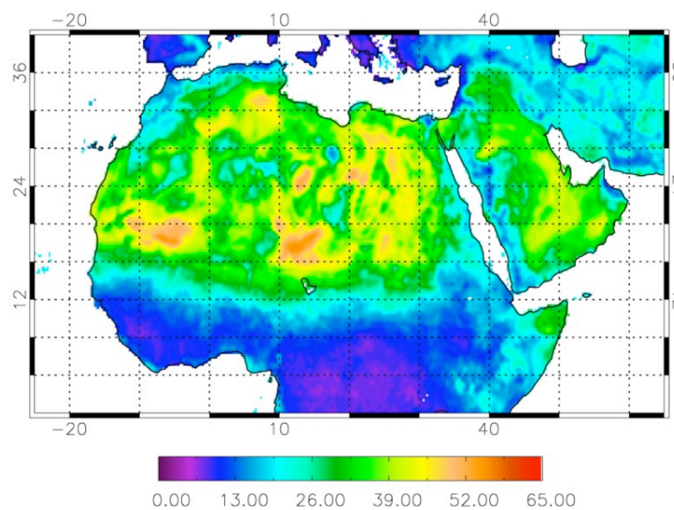


1200



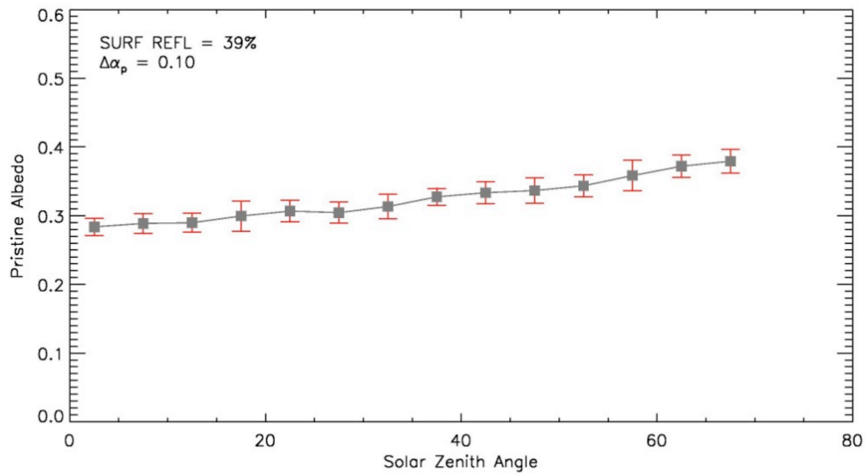
1500





GERB climatological surface reflectance for June at 0.6 µm.

Missing Values

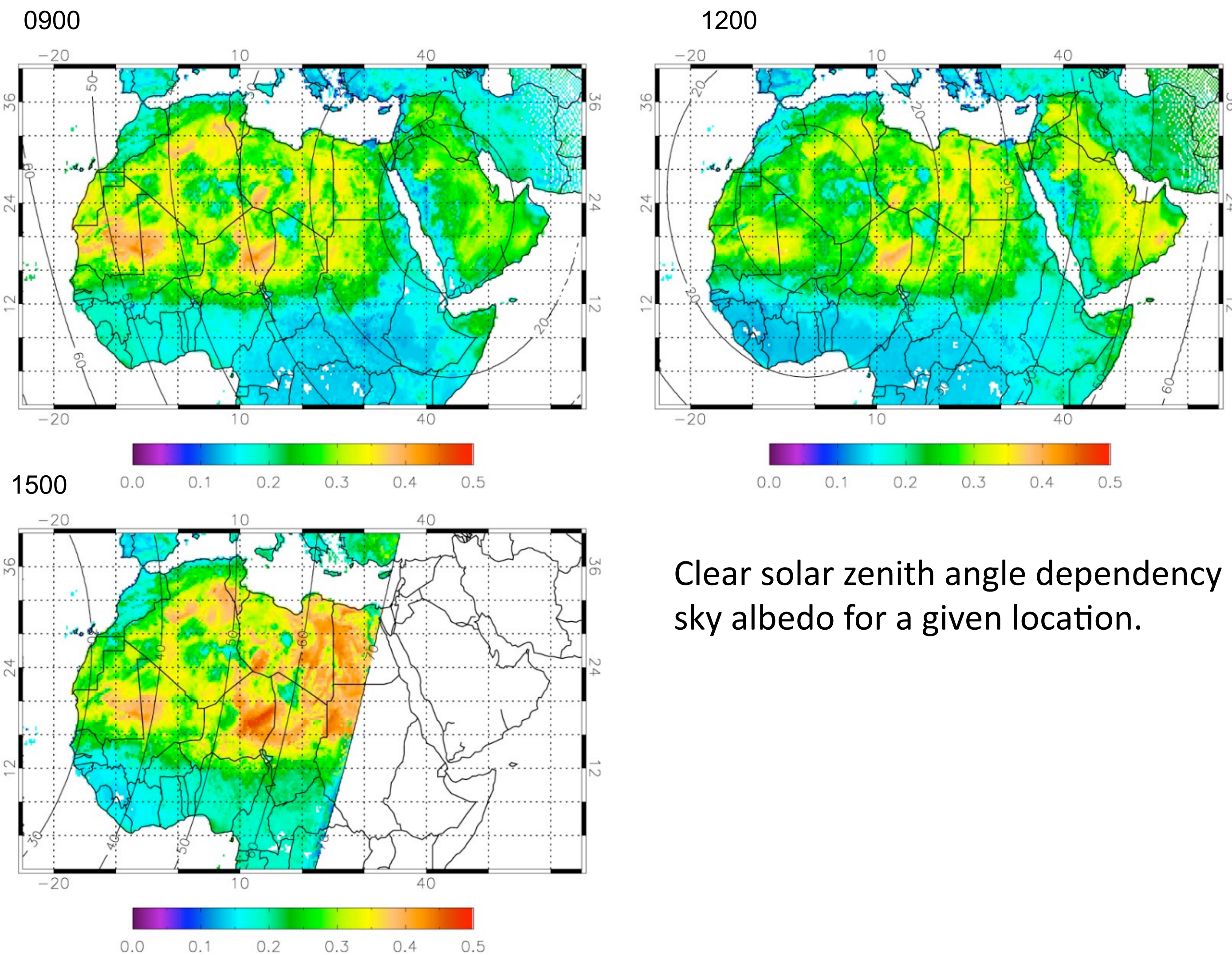


Determine a bin mean from all α_p determined via regression according to 0.25° x 0.25° averaged GERB climatological surface reflectance (R_s) and SZA (θ_z):

ΔR_s = 1% and $\Delta\theta_z$ = 5°

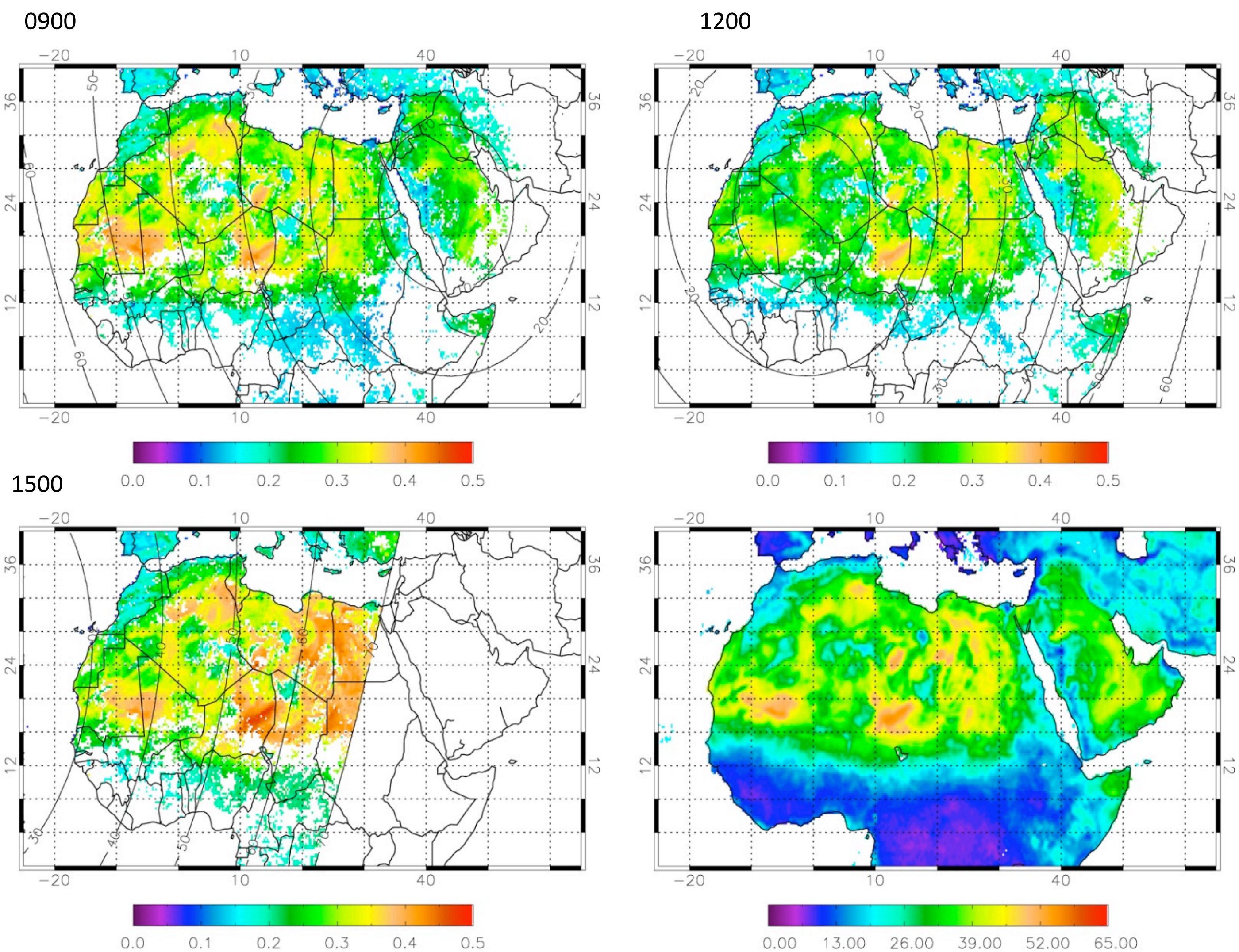
For each missing grid box interpolate over θ_z and R_s to obtain α_p.

Derived Pristine Sky



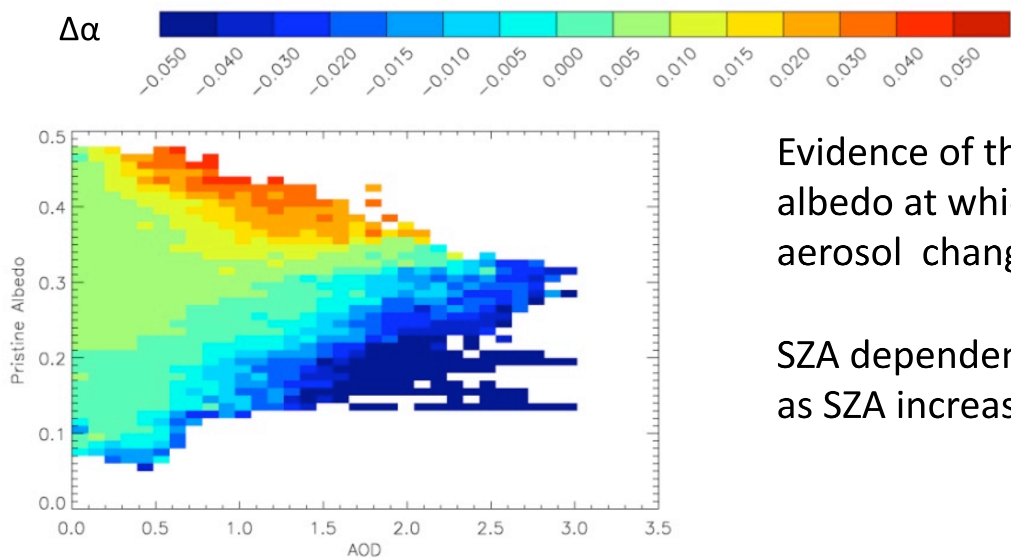
Clear solar zenith angle dependency of the pristine sky albedo for a given location.

Derived Pristine Sky



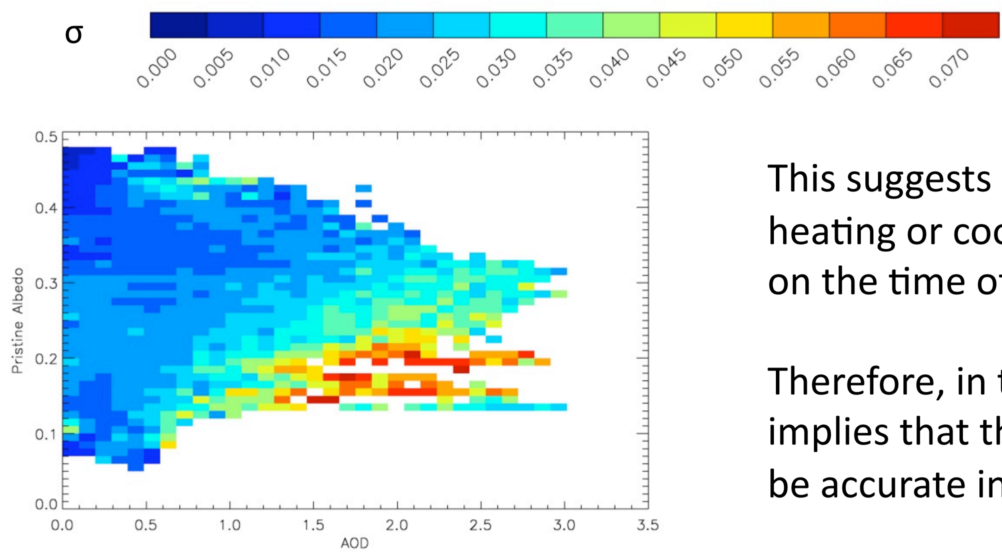
GERB climatological surface reflectance for June at 0.6 µm.

SWDRE



Evidence of the critical albedo – underlying surface albedo at which the SW radiative effect of mineral dust aerosol changes from heating to cooling.

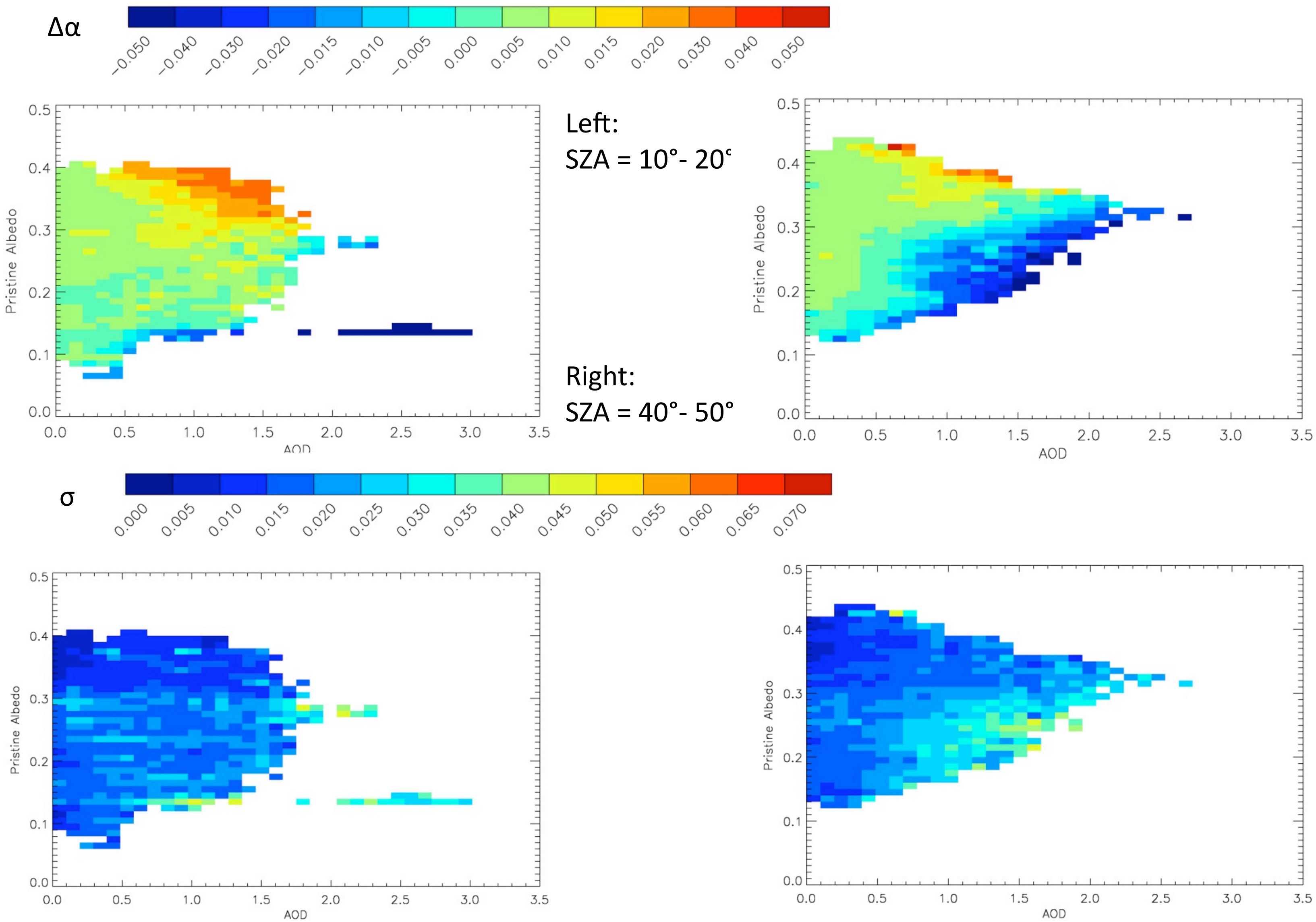
SZA dependency of α_p showed an increase in $\alpha_p \approx 0.1$ as SZA increases from 0° to 70°.



This suggests that the same dust loading could induce heating or cooling over the same location depending on the time of day.

Therefore, in terms of aerosol assimilation this study implies that the evolution of AOD with time needs to be accurate in order to correctly determine TOA fluxes.

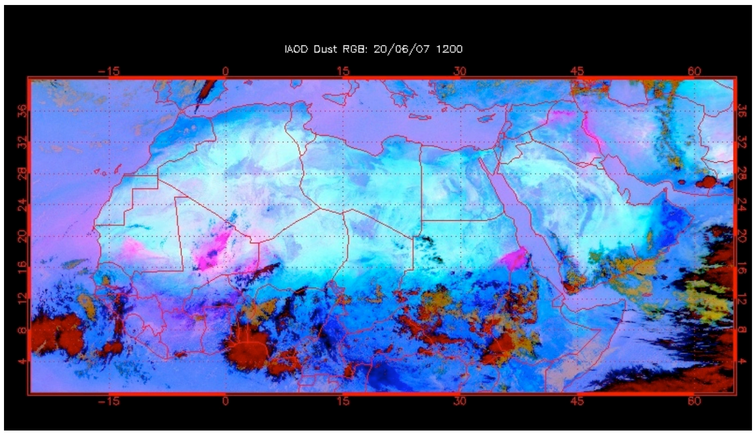
SWDRE

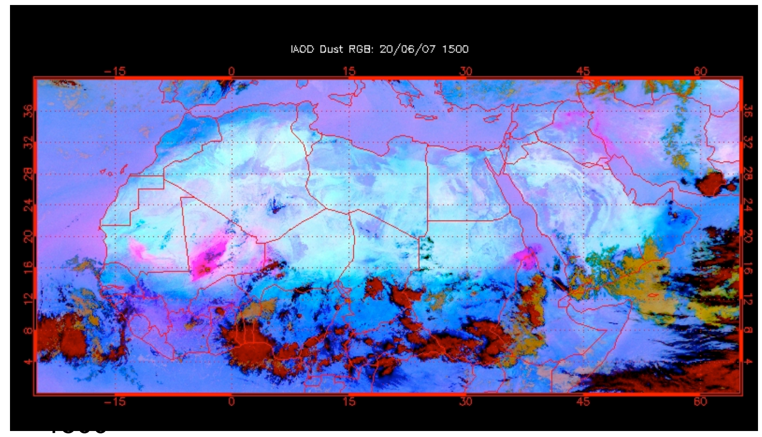


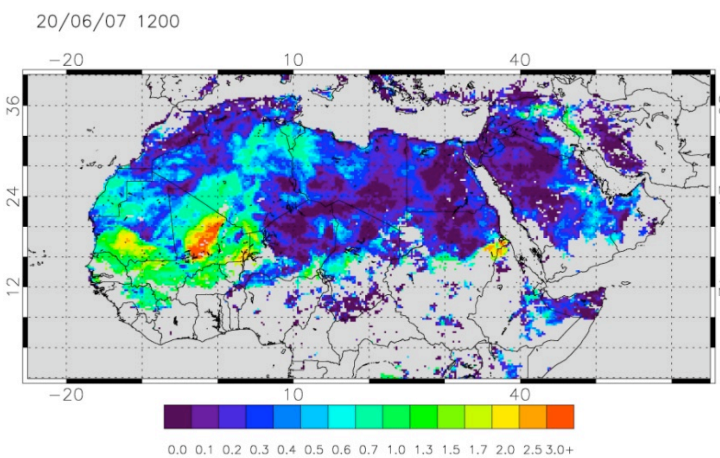
Left:
SZA = 10°- 20°

Right:
SZA = 40°- 50°

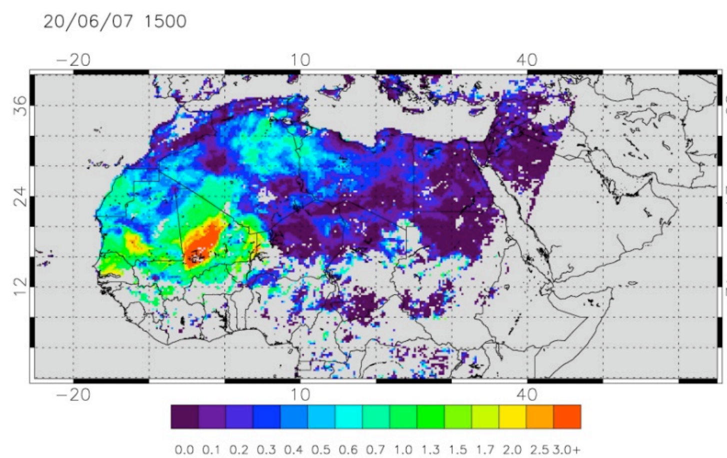
20/06/07





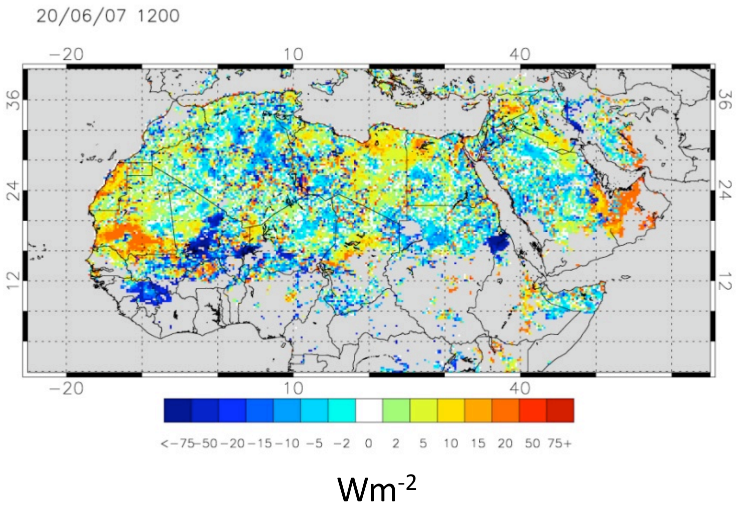


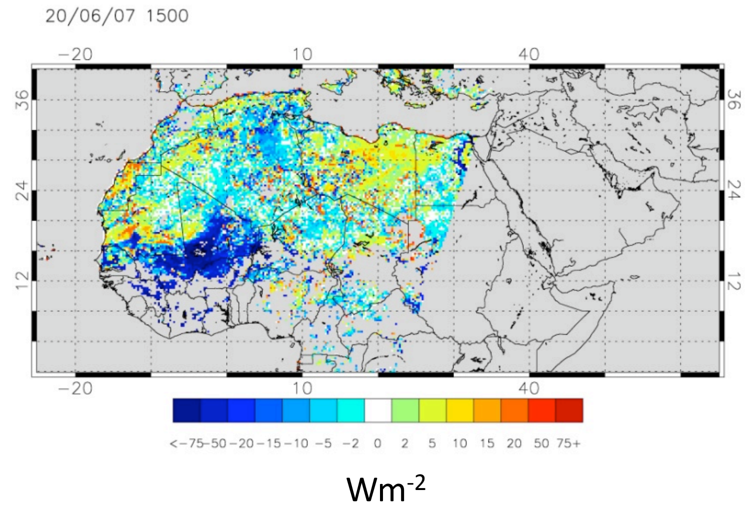
AOD (550 nm)



AOD (550 nm)

20/06/07





Large dust outbreak on 20/06/07 corresponding to aerosol optical depths between 1 and 2 in West Africa.

Contribution to upwelling SW radiation is dominated by the dust layer rather than surface.

Angular dependency of dust interaction with radiation then dominates heating or cooling effect.

Summary

- Highlighted the importance of mineral dust aerosol assimilation into NWP models.
- Explained a methodology for determining the SWDRE of mineral dust over West Africa.
- Preliminary results from applying this method to June 2007 have shown the trends which are expected from simulations and the importance of the effect of dust aerosol on instantaneous fluxes.
- The preliminary results also highlight the benefit of having full time of day data available from SEVIRI and GERB in relation to the solar zenith angle dependency of pristine sky albedo and dust interaction with SW radiation.
- In the near future, the Met Office aim to run a longer trial assimilation of AODs which will be compared with GERB fluxes. Combine the derived SW effect with the LW effect already determined for the period to produce a net effect for comparison with simulations.

LWDRE Methodology

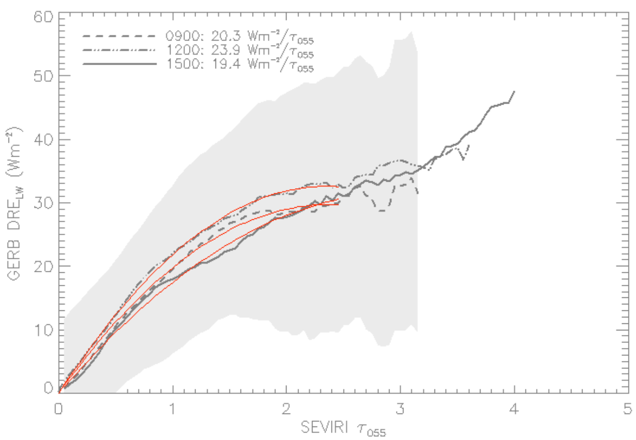
LW direct radiative effect using method of *Brindley* (*2007*).

For each pixel:

- The maximum OLR in 16 days preceding a retrieval is identified as the 'clear sky' OLR.
- T_{sfc} and RHUM fields from ERA-Interim are used to correct for changes in OLR due to changing atmospheric conditions between retrieval and 'clear sky' day.

$$\Delta OLR_{dust} = (OLR_{max} + OLR_{p}) - OLR_{retrieval}$$

$$\Delta OLR_{p} = b_1 \times \Delta T_{sfc} + b_2 \times \ln\left[\frac{LTH}{LTH_{max}}\right] + b_3 \times \ln\left[\frac{UTH}{UTH_{max}}\right]$$



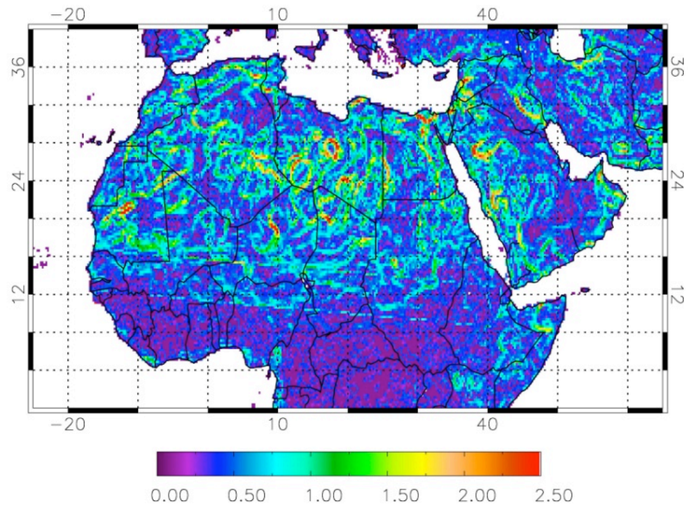
Coefficients b_n quantify the LW radiative impact of changes in atmospheric conditions between 'max' observation and retrieval. Determined from simulations of pristine sky OLR under varying atmospheric
conditions.

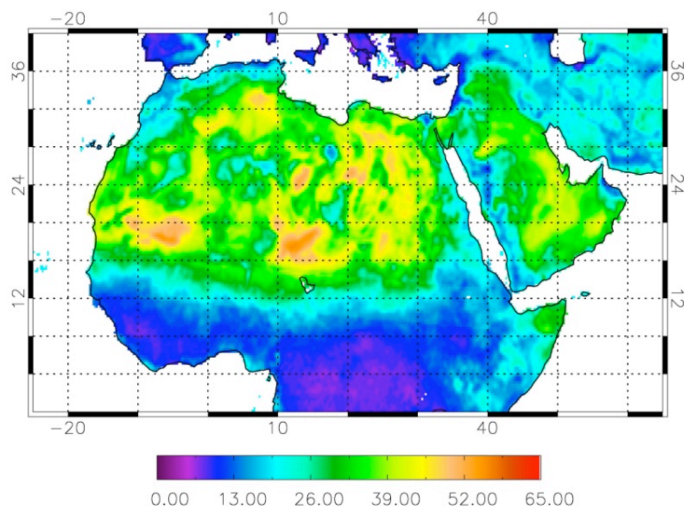
Uncertainty

Potential Sources of Uncertainty:

- Assumes that the surface albedo does not vary significantly across 0.25° x 0.25° latitude-longitude box.
- Uncertainty on y-intercept from linear regression.
- Uncertainty on SEVIRI retrieved AOD leading to uncertainty in the slope of regression.
- Uncertainty on GERB fluxes.

Uncertainty





So basically quite a bit of error on 0.25 x 0.25 box but to be smaller – fewer measurements. So if had a lot more data then would be fine.

Uncertainty

$$(\Delta\alpha_p)^2 = (\Delta y_0)^2 + \left(\frac{\partial\alpha}{\partial\tau}\Delta\tau\right)^2 + (\Delta R_s)^2$$

So you find that a lot of the points where the sdv of the rs was large are where the regression failed anyway...

Plot shows 0900 total sdv includign rs